TREATMENT OF WATER FOR LOCOMOTIVE USE[1]

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Most of the railroads in the central part of this country use some kind of water treatment to reduce boiler troubles resulting from use of water more or less high in incrusting matter. Some roads are pretty well equipped with softeners, which by use of lime and soda ash remove practically all of the incrusting solids; some roads have these softeners for their worst waters only, some use proprietary anti-scaling compounds, and others use soda ash alone as a means of preventing scale formation in their boilers. It is the purpose of this paper to deal with the last-named and to outline the methods of applying the soda ash treatment, its advantages and disadvantages and the results obtainable.

Water as it is pumped contains two classes of mineral salts the amounts of which determine its fitness or unfitness for locomotive use, the incrusting salts and the alkali salts. The incrusting salts or "total hardness" may be divided into the carbonate hardness, mostly carbonates of lime and magnesia, and the "sulphate hardness" mostly sulphates of lime and magnesia. When water is boiled at atmospheric pressure or higher the carbonates precipitate, either as soft mud or a bulky scale on the heating surfaces. The sulphate hardness remains in solution up to 60 pounds pressure, but above that it crystallizes as a very hard porcelain-like scale on the heating surface. Metal surfaces thus insulated by this scale become much overheated, resulting in leaky flues, staybolts and shortened life of firebox sheets.

The alkali salts are usually the sulphate, carbonate and chloride of sodium. These remain in solution, increasing in amount as more water is boiled away, until such a concentration is reached that the water begins to "foam." Waters high in alkali salts are, on account of their tendency to cause foaming, undesirable for boiler use. It is usually possible in Illinois to find water low in alkali

[1] Read at meeting of Illinois Section, American Water Works Association, March 10, 1915.

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salts so the foaming trouble seldom bothers until the hard waters are made mildly alkali by treating them with soda ash. Farther west railroads often have to use waters high in alkali salts which cause acute foaming trouble, although this trouble is lessened by special treatment. In addition to these mineral salts surface waters at times carry considerable suspended matter, and decayed animal and vegetable matter, which aggravate the foaming tendency.

CAUSES OF BOILER TROUBLES

The primary cause of leaky flues, fireboxes and staybolts is unequal expansion and contraction brought about by overheating of the metal, due to it being insulated from the water by a layer of scale. These troubles will be accentuated by any sudden cooling of the metal such as might be caused by holes in the fire, working engine very hard and then suddenly shutting off steam and leaving shut off for some time, cold water from injector falling to bottom of boiler, and to washing boilers with cold water.

The average operating official does not concern himself with the condition of boilers as long as the engines are going over the road in good time without failing. The flues may have considerable scale on them and with careful boiler work get along in the summer without much leaking trouble, but cold weather soon starts an epidemic of engine failures on account of leaking boiler, and it is then that the need of water treatment makes itself felt. The chemist usually starts first after the district that is showing the most leaking failures, for a leaking failure means delay to traffic, and sending out another engine and crew to pull in the train and failed engine. This costs considerable money besides requiring additional engines where such failures are frequent.

TREATMENT

The prevention of scale formation may be accomplished by using water softeners which remove practically all of the hardness and suspended solids, or by treating each water with enough soda ash to neutralize the sulphate hardness, and provide a slight excess of soda ash, all of the scale forming solids being converted into a soft sludge which can be readily blown out through a properly located blow-off cock. Soda ash or sodium carbonate is found in some waters, and unless it is so high as to cause foaming trouble, waters of this type are desirable for boiler purposes in that they will not

form scale and require no treatment; but unfortunately most waters contain sulphate hardness and must be treated.

The soda ash is changed to sodium sulphate in the boiler, and locomotive boilers worked to full capacity and using surface waters will usually be in a foaming condition when this sodium sulphate and other sodium salts, in water from the boiler are over 2000 parts per million. Where only clear well waters are used this limit will be 2500 or even higher, and in stationary boilers, with their lower rate of evaporation and greater steam space, the foaming point may be 5000 to 6000 parts per million. The mud and carbonates precipitated in the boiler, if allowed to accumulate, may cause trouble in three ways:

1. The foaming tendency of the water in the boiler increases.
2. Heavier scale will form at times when treatment is light.
3. There is danger from mud-burning.

It is essential, therefore, that engines using soda ash treated water be equipped with suitable blow-off arrangement for removing the sludge from the boiler. Critical examinations of the deposits in boilers have shown that, where there is scale formation, the heavier pieces of scale drop out in the barrel and front of the side legs, while the lighter scales and mud are carried further back by the circulation of the water and deposited in the back of the side legs and in back water leg. With properly treated water there is no scale formation, and the sludge can best be removed by means of a perforated pipe extending across and lying on the back mud ring and connected to a blow-off cock located at back corner. The primary purpose of this blow-off cock is to keep the alkali salts in the boiler below the foaming point. Incidentally the sludge is removed, and where treatment is maintained full and continuous, engines can be run indefinitely without having to wash out boiler. The federal law requires boilers to be washed at least every 30 days, but where waters are high in incrusting matter a deficiency of treatment will result in rapid scale formation, and on such districts it is wise to wash boilers every two weeks rather than risk scale banks and burned sheets, if, by lack of supervision, neglect or other cause, treatment had become light. One passenger engine ran 10,000 miles without washout or change of water on an Illinois division using waters of average hardness of 280 parts per million and treated with one-half pound soda ash per 1000 gallons, yet at the end of the test the boiler showed no scale formation and only a small amount of soft sludge in side water legs.

AMOUNT OF BLOWING OUT NECESSARY

A pound of soda ash forms 1.34 pounds of sodium sulphate, and calculations show that when 12.42 pounds of soda ash have been used per 1000 gallons of water in the boiler, the sodium sulphate will amount to 2000 parts per million, and to prevent foaming water must be changed completely or enough blown out to keep concentration below 2000. A treatment of 1 pound soda ash per 1000 gallons necessitates blowing out $\frac{1}{12.42}$ or 8.05 per cent of the water used, $\frac{1}{2}$ pound per 1000 gallons, 4 per cent, etc. In stationary practice, where higher concentration can be carried, the amount of blowing off is much less.

This waste at the blow-off cock is the expensive item against water treatment. A pound of soda ash entails a waste of 80.5 gallons of water that has been heated to the temperature of boiler pressure steam, and a locomotive boiler carrying 200 pounds of steam will use 30.5 pounds of Illinois coal to heat this water. At $1.50 per ton this coal will cost 2.29 cents, the 80 gallons of water at 5 cents per 1000 gallons 0.4 cent, a total of 2.69 cents per pound of soda ash used. This will be less with lower steam pressures and where a higher concentration than 2000 can be carried, and there is of course no waste while bringing the water up to this foaming point.

Where treatment is heavy or waters contain considerable natural alkali, it becomes impractical to do the necessary blowing off, and it is cheaper and more satisfactory to change water in boiler frequently at terminals, or use some anti-foaming compound that allows a higher concentration of alkali salts before foaming occurs. Passenger engines should be washed out or have water changed often enough so that the terminal blowing off will keep the boiler from foaming without having to blow out en route.

The following procedure should be followed to overcome boiler troubles on any certain division.

First, get the best available water supply; second, provide suitable arrangements for blowing off engines and line up to have engines blown systematically at terminal and on road; third, treat all waters containing sulphate hardness with the necessary amount of soda ash, and fourth, provide sufficient chemical supervision, to maintain correct treatment at all times.

WATER SUPPLIES

Chemical analyses of the water in use for locomotives should be made, and where the sulphate hardness or the alkali salts are high, an effort should be made to locate a better supply that can be substituted at not prohibitive expense. In the past, railroads usually took the first water available, regardless of the quality, and there are many places where these old supplies, high in sulphate hardness, can easily be replaced by much softer water. The cost of treating the waters with the attendant cost of coal wasted as a result of this treatment should be considered in changing supplies, and it will usually be found that the better water will pay for itself in a short time.

BLOWING OFF BOILER

At roundhouses there should be a place for blowing off just before engine goes on to clinker pit, and hostlers should be instructed to blow out full glass of water from every incoming engine and should be held strictly to account for obeying these instructions. It is also a good plan to provide a similar arrangement on outgoing track to give enginemen opportunity to blow off before leaving. Enginemen are instructed through letters explaining the water treatment, blowing off, etc., and individually by their road foremen.

TREATMENT

Our methods of analysis may not appeal to the chemist, but we determine only the total dissolved solids, the total hardness by soap test, and the sulphate hardness by subtracting the alkalinity to methylorange from the total hardness. Every water containing sulphate hardness is treated with enough soda ash to neutralize this sulphate and provide excess, such that waters taken from boilers of engines using the treated water will show about 15 per cent of the total alkali salts as sodium carbonate. Probably only 5 per cent will keep the water in a non-incrusting condition unless the hardness is high, but the 15 per cent is carried as insurance against occasional neglect or deficiency of treatment at some stations.

The soda ash solution would best be used evenly according to the flow of water, and should go through a separate pipe line to the water tank so there will be a chance for chemical reaction before the

treated water passes into the pipe lines. The solution may be introduced by small steam pump, by plunger pump operated by main pump or water motor through which all the water passes; it may be forced continuously by air pressure, solution passing through a $\frac{3}{32}$-inch diameter hole; by a by-pass arrangement in which part of the water is by-passed from the main and displaces the solution in proportion to the water flowing; and when no other method is available it may be placed direct in engine tanks.

SUPERVISION OF TREATMENT

A very important feature of treating waters with soda ash alone is to provide enough chemical inspection and supervision to insure keeping all waters treated fully and with as little interruption as possible. If the treatment is light on account of neglect of pumpers or insufficient soda ash called for in directions so that the treated waters in general still show some sulphate hardness, then the only benefit is in the small decrease in hardness of the water, due to some precipitation of the carbonates in the supply tub. The foaming tendency of the water will have increased in proportion to the amount of soda ash used, and boiler must be blown off nearly as much as with full treatment; but the hard scale still forms on the flues and causes the leaking troubles that the soda ash is expected to cure. To keep treatment right a road water inspector should make frequent analyses of the raw and treated waters for sulphate hardness or sodium carbonate, and should also inspect apparatus for treatment. If this inspection shows treatment wrong he should do what he can on the ground toward adjusting matters, and report to division officials when other steps are necessary to correct pumper or repair apparatus. On some divisions where the raw waters do not vary much in quality at different times of the year and where there is a dependable class of men handling the soda ash, it will not be necessary to provide so much chemical supervision after treatment has been started and is going satisfactorily, and one water inspector may be able to handle two or three such divisions. On other divisions where the waters vary considerably in quality, where the pumpers are changing frequently or where slight falling off in treatment is followed quickly by boilers leaking, it pays to keep a water inspector on the division all the time.

RESULTS OF TREATMENT

The advantages gained by full and systematic treatment of water are as follows:

1. Engine failures due to leaky boilers are reduced to a minimum. On divisions where soda ash treatment has been in use for several years the records show an average mileage per engine failure due to leaky flues of 513,000 miles. The total yearly mileage on these divisions is about 10,000,000, all waters are treated and most of the engines are heavy power with flues 19 and 21 feet long.
2. Much less boiler work is needed, mileage of flues between shopping is materially increased and the cost of boiler repairs is correspondingly decreased. It is not necessary to shop an engine for flues before the machinery needs it.
3. Mileage between washings of boiler is increased.
4. There is a saving of fuel due to having boiler free from scale. Also a saving of the fuel that heats the water lost from leaking boilers.
5. Engine is not held out of service so much for washing and working on boiler.

The disadvantages are the increased foaming tendency of the treated water and the waste of coal and water in blowing off to overcome this foaming tendency.

The cost of water treatment can be given fairly closely, but it is rather difficult to give in dollars and cents the various savings due to treatment. Some estimates of these costs and savings are given here as so much per engine per year based on a freight engine of about 50,000 pounds tractive force using waters treated with an average of one-half pound soda ash per 1000 gallons.

Saving per engine per year

Boiler repairs	$250.00
Fuel 5 per cent of $7200	360.00
Washing boiler	40.00
Ten days extra service at $15 per day	150.00
	$800.00

Cost per engine per year

Soda ash 3000 lbs. at 0.85 ct. per lb	$25.50
Coal wasted 45.8 tons at $1.50	68.70
Water wasted 240,000 gals. at $.05 per 1000 gals	12.00
Supervision of treatment at 0.2 ct. per 1000 gals	12.00
	$118.20
Net saving per engine per year	$681.80

These figures are for a large engine under average water conditions. Where the waters are hard the saving in boiler repairs and fuel wasted on account of scaled boiler would be considerably higher. A number of years ago Professor Schmidt of the University of Illinois in tests on an Illinois Central engine reported a saving of 10 per cent in a clean boiler over the boiler with scale of average thickness $\frac{1}{16}$ inch. The percentage will run higher with heavier scale, and the assumption of a 5 per cent saving is conservative. The above net saving of $681.80 multiplied by a number of engines runs into a large amount of money, and shows the financial advantages of water treatment for a railroad.

Before closing the writer would like to say a word about treatment with barium salts. The great objection to the use of soda ash is the increased foaming tendency of the treated water, and this bad feature keeps many railroads and power plants from using soda ash. Barium hydrate precipitates the sulphate hardness, an equal amount of carbonate hardness and does not increase the soluble salts or foaming tendency of the water. It is therefore rather ideal for water treatment, but thus far has not come into general use on account of its high price. Barium carbonate is being used in Germany for water softening, it is just as cheap as soda ash, and has not the foaming objection. Settling tanks are necessary with the barium treatment, involving a larger initial outlay than with soda ash. Development of processes for using barium carbonate or decreasing the cost of making barium hydrate would increase very much the amount of water softened for boiler purposes.